

11/PRK¹

SEMICONDUCTOR SENSOR WITH FRONT-
SIDE CONTACTING

The present invention concerns a semiconductor sensor, especially a so-called ISFET or CHEMFET sensor, which includes an ion-sensitive, field effect transistor. The ion-sensitive elements, which are present in the form of chips, must, in order to realize their purpose, be mounted such that they can, on the one hand, be subjected to the usually highly corrosive samples, without that, on the other hand, corrosion-susceptible components, such as conductive traces, come in contact with the media. To this end, the ion-sensitive element of a semiconductor chip is usually arranged aligned with an opening in a wall of a sample chamber, with an annular seal being arranged between the wall of the sample chamber and the semiconductor chip. The annular seal surrounds the opening, so that the ion-sensitive region of the semiconductor chip can be subjected to the sample, without the sample being able to reach the areas of the chip outside of the ion sensitive region.

The electric contacting of the chip proves, however, to be difficult. The state of the art uses essentially three approaches. Benton discloses in US Patent No. 5,833,824 a pH-sensor, in which an ISFET chip is secured on the underside of a substrate by means of a metal seal, which surrounds the ion-sensitive region of the ISFET chip, with the ion-sensitive region being aligned with an opening in the substrate. Outside of the region surrounded by the seal, conductive traces on the surface of the chip extend to contact surfaces, which are connected via solder or weld connections with complementary contact surfaces on the underside of the substrate. The solution proposed by Benton is very expensive in the respect that both during the manufacture of the seal and also during the effecting of the electrical contacting, expensive soldering and/or welding processes are required.

The state of the art discussed in Benton describes ISFET sensors, in which an ordinary polymeric seal is arranged about the opening of the sample chamber wall between the substrate and the ion-sensitive region of the ISFET chip. The contacting of the ISFET chip occurs, however, not to the substrate, in the sense of Benton, but, instead, to a support, which supports the ISFET chip on the rear side facing away from the substrate. To this end, bond wires are extended between contact surfaces on the front side of the ISFET chip to contact surfaces on the support outside of the bearing surface of the ISFET chip. Even this solution is expensive, because solder work is required for contacting the chip and because, in order to assure the functioning and integrity of the sensor, the chip must be placed within narrow tolerances with respect both to the substrate and the support.

Additionally, solutions are known, in which the chips have their contact surfaces, or bond pads, on the rear side facing away from the ion-sensitive region. These chips can then be contacted on the rear side via a support having complementary contact surfaces, wherein, for assuring sufficient, galvanic contacts between the rear side of the chip and the support, an anisotropic, elastic conductor, e.g. a silicone film with embedded gold filaments, is arranged in a direction perpendicular to the plane of the film.

This solution is very costly in the respect that the leading of the electrical contacts through the chip from its front side to its rear side increases its manufacturing costs several times.

It is, therefore, an object of the present invention to provide a semiconductor sensor that overcomes the described disadvantages. The object is achieved according to the invention by the sensor of the independent claim 1.

The sensor of the invention includes: A semiconductor chip having a first surface, which has a media-sensitive region and at least one, first, electrical contact surface; and a support having a second surface, which faces the first surface of the semiconductor chip, has an opening aligned with the sensitive

region, and at least one, second, electrical contact surface, which overlaps, or aligns, with the at least one, first, electrical contact surface; wherein, between the support and the semiconductor chip, a preferably elastic, anisotropic conductor is arranged, which produces a conducting connection
5 between the at least one, first, contact surface and the at least one, second, contact surface; wherein the film or layer has a traversing opening aligned with the opening in the second surface, so that the sensitive region of the semiconductor chip can be contacted through the opening with an analyte; wherein the preferably elastic, anisotropic conductor seals the region outside
10 of the opening against contamination with the analyte.

Preferably, the anisotropic conductor comprises an elastic, insulating, organic layer with embedded, conductive particles, grains or filaments, especially metal particles, or filaments. Especially preferred at this time are
15 gold filaments, which extend perpendicularly to the plane of the elastic, organic layer. Especially preferred at this time are silicone layers, which have gold filaments and are available commercially from the firm Shin-Etsu.

To the extent that the organic, elastic layer has metal grains, these are, in a
20 relaxed state of the layer, uniformly distributed in the layer in a concentration such that there are insufficient electrical contacts between grains to produce an electrical conductivity over large distances. If, however, the elastic layer is compressed in one direction, for example from clamping when serving as a sealing element, then a sufficient number of electrical contacts arise in the
25 direction of compression that conductivity in the direction of compression is assured.

Independently of the selected type of sealing element, the semiconductor chip is preferably pressed by a rear-side support against the elastic layer, in
30 order to optimize the sealing action of the elastic layer. The rear-side support can be both stiff and elastically prestressed. The elastic prestress, e.g. by way of a coil spring, is advantageous in that the effects of differing coefficients of thermal expansion can be accommodated better, compared

with when this must occur solely on the basis of the elasticity of the sealing element. This is especially important, when a certain degree of compression of the sealing element is required, in order to assure the electrical conductivity through the seal.

5

Further details will become apparent from the accompanying drawings, the figures of which show as follows:

Fig. 1 a plan view onto the underside of a substrate for a semiconductor
10 sensor of the invention;

Fig. 2 a sealing element for a semiconductor sensor of the invention; and

Fig. 3 a longitudinal section through a semiconductor sensor of the invention.
15

Fig. 1 shows the underside of a substrate for a semiconductor sensor of the invention. Contact surfaces 8, 9 are arranged on the underside, spaced from an opening 7. Contact surfaces 8, 9 are connected via conductive traces 10, 11 with junctions as required. In completed assembly of the
20 sensor, opening 7 serves to permit contacting of the semiconductor chip with sample to be analyzed.

Fig. 2 shows a plan view of a sealing element 5 for the semiconductor sensor of the present invention, with the sealing element of this embodiment
25 comprising a silicone layer, which contains traversing gold filaments, which extend essentially perpendicular to the plane of the sealing element. In this way, the sealing element is insulating in the plane of the sealing element and conductive perpendicular to the plane of the sealing element. Consequently, mutually aligned, electric contact surfaces mutually separated by the seal,
30 can nevertheless be in electrical contact with one another, while contact surfaces laterally displaced from one another in the plane of the sealing element are electrically insulated from one another.

The required minimum size of aligned contact surfaces for assuring a safe contact is a question of the average number of gold filaments per unit surface area of the sealing element. This parameter can be coordinated in suitable manner by those skilled in the art. In the same way, the average
5 lateral separation of components for assuring a reliable insulating is a function of the number density of gold filaments, as well as their orientation and their diameter. Presently, a sealing element is preferred, which enables a reliable contacting of aligned contact surfaces of some few square millimeters and a sufficient insulation at a lateral separation of about 1
10 millimeter.

The outer dimensions of the sealing element of Fig. 2 are congruent in this form of embodiment with the outer dimensions of the underside of the substrate in Fig. 1; this is, however, not compulsory. It is expedient,
15 however, that the opening in the sealing element has about the same size as the opening 7 in the underside of the substrate 6.

Fig. 3 shows a longitudinal section through the assembled semiconductor sensor of the present invention, wherein the sealing element 5 is clamped
20 between a semiconductor chip 1 and the substrate 6.

The semiconductor chip 1 has, in its surface facing the sealing element, an ion-sensitive region 4, which aligns with the opening 7 of substrate 6. Spaced from the opening are contact surfaces 2 and 3, which align with the
25 complementary contact surfaces 8, 9 on the underside of the substrate. The contacting between the chip-side contact surfaces 2, 3 and the substrate-side contact surfaces 8, 9 is assured by the conductivity of the sealing element perpendicular to its plane.

30 In order to achieve a sufficient sealing, the semiconductor chip 1 must be pressed with sufficient force against the underside of the substrate 6. This can, on the one hand, occur by a clamping with dimensionally stable

structural elements (not shown), and, on the other hand, by elastic elements, such as e.g. a coil spring (not shown).

5 The substrate 6 can be formed e.g. as one piece with a housing of a semiconductor sensor or as a separate component, which is installed in suitable manner into a housing. These and similar embodiments will be apparent to those skilled in the art on the basis of what has been described above and lie within the scope of the invention, as such is defined in the patent claims below.